Disruptive Innovations in Technologies &
The Tectonic Shift in the Landscape of Transportation

Ching-Yao Chan
California PATH, UC Berkeley

Modern Engineering & Technology Seminar (METS)
Session: Intelligent Transportation Integrated Systems
October 24-25, 2016
“創新與分配是矛盾的”

“創新是必要的，但也要有心理準備必須忍受一些問題”

“創新是分配最大的罪魁禍首”

- 臺積電董事長張忠謀，新聞報導 10/24/2016
The Tectonic Shift in Transportation

Transportation (Auto, Transit, Travel Services)

Mobility Service

Connectivity, Automation, Technology, Data Science, AI, etc.

Infotainment, Telematics, etc.
Presentation Outline

• Recent Investment Activities in Transportation
  • Rising Acquisitions and Investments
  • Cross-Currents between Auto and High-Tech

• Transformation and Disruption, Case Studies
  • Traffic Data and Traveler Information
  • Mobility Services

• Connected and Automated Vehicles
  • Functional Needs and Technologies
  • Renaissance of Mapping Sector
  • Artificial Intelligence

• A Look toward the Future
A Craze for Acquisition

- Total value of automotive-supplier deals in 2015 and 2016 was $74.4 billion, per Bloomberg.

- Each of those years far exceeding the $17.7 billions annual average in the previous 10 years.

- The number of transactions valued at $500 millions or more also skyrocketed to 18 in 2015, triple the level of the previous decade.

- There have been 12 (as of 09/16) such deals so far in 2016.
<table>
<thead>
<tr>
<th>Time</th>
<th>Buyer /Investor</th>
<th>Target /Recipient</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2015</td>
<td>Audi, BMW, M-B</td>
<td>HERE</td>
</tr>
<tr>
<td>November 2015</td>
<td>Toyota</td>
<td>Toyota Research Institute</td>
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<tr>
<td>January 2016</td>
<td>GM</td>
<td>LYFT</td>
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<td>March 2016</td>
<td>GM</td>
<td>Cruise Automation</td>
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<td>May 2016</td>
<td>VW</td>
<td>GETT</td>
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<tr>
<td>May 2016</td>
<td>Apple</td>
<td>DiDi Chuxing</td>
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<tr>
<td>May 2016</td>
<td>Toyota</td>
<td>UBER</td>
</tr>
<tr>
<td>August 2016</td>
<td>DiDi Chuxing</td>
<td>UBER China</td>
</tr>
</tbody>
</table>
# A Global Drive for AV and EV

Some Highest-Valued Companies (as of 09/16) in Asia have direct investments in AV and EV

<table>
<thead>
<tr>
<th>Company</th>
<th>Home</th>
<th>Market capitalization, in billions*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tencent Holdings</td>
<td>China</td>
<td>$248</td>
</tr>
<tr>
<td>Alibaba Group</td>
<td>China</td>
<td>242</td>
</tr>
<tr>
<td>Samsung Electronics</td>
<td>South Korea</td>
<td>235</td>
</tr>
<tr>
<td>TSMC</td>
<td>Taiwan</td>
<td>145</td>
</tr>
<tr>
<td>Tata Consultancy Services</td>
<td>India</td>
<td>78</td>
</tr>
<tr>
<td>SoftBank Group</td>
<td>Japan</td>
<td>77</td>
</tr>
<tr>
<td>Baidu</td>
<td>China</td>
<td>61</td>
</tr>
<tr>
<td>Keyence</td>
<td>Japan</td>
<td>43</td>
</tr>
<tr>
<td>Hon Hai Precision Industry</td>
<td>Taiwan</td>
<td>43</td>
</tr>
<tr>
<td>Sony</td>
<td>Japan</td>
<td>41</td>
</tr>
</tbody>
</table>
Major Themes of Recent Investments

• Evaluation of **High-Tech investments** much higher than traditional values in auto industry

• **Shared mobility (ride hailing) services** attracting significant investments

• **High interest in self-driving technologies**

• **Software content** a major focus

• **(Deep) Machine Learning** an active field
How Big is the Pie (in the Sky)?

- Driverless vehicles are poised to threaten the $570 billions that Americans spend each year on new cars.

- Auto industry revenue at $2.3 trillions a year globally.

- At stake is a transportation services market (ride sharing and bus services) that is worth $5.4 trillion, per estimate by one report.

- Now carmakers (feel that they) must be in the businesses of ride-hailing apps, shuttle buses, 3D maps, and computation/machine learning.
Transformations and Disruptions in Transportation

Illustration by Case Studies
Traffic Data and Traveler Information (Older Model)

- Data Model:
  - Limited Data Set
  - Minimal Processing & Integration

- Business model:
  - Tax (public)
  - Advertisement (private)
Traffic Data and Traveler Information (Newer Model)

- Live reporting (police, helicopter, phone calls)
- Infrastructure Sensing (camera, radar, loop, etc.)
- User and Customers
- Data Provider
  - Fleet Data (probe data)
  - Subscriber Vehicle data + reporting
- Traffic Management Center
- Radio Stations
- Message Sign
- In-Vehicle Display
- Nomadic Device
Breakdown of Functional Needs (Newer Model)

- Infrastructure
  - Sensing (camera, radar, loop, etc.)
- Live reporting (police, helicopter, phone calls)
- Radio Stations
- Message Sign
- In-vehicle display
- Nomadic device
- Data Collection
- Data Integration
- Data Dissemination
- Fleet Data (probe data)
- Subscriber vehicle data + reporting
Business Models and Exemplar Players (Newer Model)

Data Collection
- Crowd-Sourced Data (e.g. WAZE)

Data Integration
- Data Fusion (e.g. INRIX)

Data Dissemination
- Data Everything (e.g. Google)
Transformations and Disruptions

Traffic Data and Traveler Information

• What do customers gain?
  – Enhanced services with enriched content
  – Customized Delivery

• Transformations
  – Technology-centric with a strong link to ICT industry
  – User becomes an integral part of data structure
  – Data mining opportunities and enhanced services via cloud services

• Disruptions
  – Diminishing prospects for old providers
  – Emerging new data reseller & subscriber services
  – Realignment of public agencies’ strategies (SF MTC as an example)
Transformations in Mobility Services

Connectivity

Shared Economy

Data Analytics

Mobile App
UBER - A Trailblazer in Mobility Services

Uber's Global Reach

Uber has emerged as the dominant ride or taxi hailing app in 108 of 171 countries analyzed.

Source: SimilarWeb
Emergence of the Largest Taxi Company in the World

• **UBER**
  - *A transportation network company, leveraging smartphones for ride sharing and hailing*
  - Founded in 2009
  - Official launch in SF in 2011

• As of August 2016,
  - Available in ~70 countries and ~500 cities
  - > 1M drivers
  - Reaching 2-Billionth ride milestone in 08/16
  - 2016 Revenue ~ $1B/quarter
  - Estimated market value >$60B with multiple rounds of funding by investors
Transformations and Disruptions

Mobility Service by UBER and LYFT and the like

• What do customers gain?
  – Door-to-door convenient ride service
  – Personalized account linked with family or business
  – Higher satisfaction

• Transformations
  – More timely and efficient services
  – General public involved as drivers and riders
  – Alternatives to substitute transit for travel needs (e.g. UBER collaboration with City of Summit NJ for commuter parking, 10/2016)

• Disruptions
  – Devastation of Taxi services
  – New York Taxi Cab Medallion Price cut in half, from $1M to $500k
  – SF Taxi trips drop ~70%; LA Taxi trips drop >30%
Disruptions to Automotive Industry
As a Result of New Mobility Services

• Ride sharing at lower costs than ownership
  • High costs of ownerships, cars driven only 4% of time
  • Ride sharing can cut costs by 50%

• Ride-sharing threatens the business model of automakers
  • (Automated) ride-sharing will diminish or eliminate the needs of personally owned vehicles???

→ Automated Mobility Service will further impact auto industry significantly
  → Evidenced by investments by global automakers in ride sharing and self-driving cars?
Connected and Automated Vehicles
Prevalent Trends in Transportation

- Telematics (In-Vehicle Services)
- Data Analytics and Cloud-Based Applications
- Driver Assistance Systems (ADAS)
- Mobility Service (+ or -AV)
- Environment Friendly/ EV
- Car Sharing and Ride-Sharing
<table>
<thead>
<tr>
<th>Industrial Sector</th>
<th>Selective Iconic Players</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Telmatics</td>
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<tr>
<td></td>
<td>OnStar, Verizon, etc.</td>
</tr>
<tr>
<td></td>
<td>Data Analytics</td>
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<tr>
<td></td>
<td>HERE, INRIX, etc.</td>
</tr>
<tr>
<td></td>
<td>ADAS</td>
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<tr>
<td></td>
<td>Mobileye, Carmakers</td>
</tr>
<tr>
<td></td>
<td>Mobility Service/AV</td>
</tr>
<tr>
<td></td>
<td>Google, Uber, etc.</td>
</tr>
<tr>
<td></td>
<td>Environment/EV</td>
</tr>
<tr>
<td></td>
<td>Tesla, NextEV, etc.</td>
</tr>
<tr>
<td></td>
<td>Ride Sharing</td>
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<tr>
<td></td>
<td>UBER, LYFT, etc.</td>
</tr>
</tbody>
</table>
Connectivity + Automation
Two Enabling Pillars

Connectivity

Automation

Share it
Connectivity for Telematics Services

HERE as a Case Study

- 100,000s of vehicles from BMW, Daimler, VW are set to begin feeding visual data into the HERE system

- The new live traffic services are set to hit the road in the first half of 2017

- Four services for drivers
  - video views of traffic jams or accidents
  - road hazards like fog or slippery streets
  - traffic signs including temporary speed limits
  - on-street parking

- Millions of vehicles expected to contribute live traffic feeds by the end of 2018
Societal Growth of Connectivity

High-Tech Company Shuttle Buses

• Commuting buses offered by Google, Facebook, Apple, and the like in the SF Bay Area

→ Productive employees with Wi-Fi access on board

→ ~800 buses, 34,000 passengers daily, 9.6 millions boarding in 2014 (MTC report)

→ Elimination of some 2 million car trips a year from congested city streets, and estimated 12 million vehicle miles
Leveraging Connectivity for Services

TESLA as a Case Study

- Connectivity (4G links) essential for EV battery management
  
  → Enhanced infotainment and user interface utilizing the same 4G Link
  
  → Enriched user experience, customer relationship, and telematics contents
  
  → Over-the-Air software update to enable new function (Fall 2015 Auto-Pilot Activation)
Leveraging Connectivity and Automation

*TESLA as a Case Study*

**Connectivity**
- Connectivity for EV Battery & Infotainment
- Backhaul Field Performance Data via Connectivity

**Automation**
- Over-the-Air Activation of Auto-Pilot
- Enriched Data to Improve Automation

*Over the Air*
Dissecting Automated Driving Systems

Functional Blocks and Business Sectors
Automated Driving Systems (ADS)
Automated Driving Systems (ADS)
Renaissance of Mapping Sector

Mapping for Autonomous Vehicles
New Business Models for CVs and AVs

Mapping Sector as a Case Study

- High-Definition and Data-Rich Map becomes a necessity for AVs

  → Google

  → HERE (NAVTEQ) HD-LIVE

  → TomTom Roads DNA

  → Mobileye Road Experience Management (Roadbook)

  → Startups (e.g. Civil Map, Map Box)
Four Layers of Local Dynamic Map (LDM)

2. CEN ISO EN 18750 Definition of a global concept for Local Dynamic Maps
Mapping (Exemplar Industrial Players)

- Mobileye
  - Highly Dynamic Data
- MapBox
  - Map Data Set
- TomTom
  - Basic Map Data Set
- Drive
  - Cloud Map Database
- Civil Maps
  - Survey + Probe Vehicles
  - Infra + Vehicle Sensors
  - OBU
  - Cloud + V2X
- RoadDNA
  - Onboard Sensors + V2V
  - Perception
  - Detection

LDM
- Permanent Static Map
- Transient Static Data
- Transient Dynamic Data
- Basic Map Data Set
- Map Database
Putting Its Money Where Its Mouth Is

Recent Ford Motor Investments as a Case Study

- When Ford said (08/16) that it would have self-driving cars by 2021 for the market, it also announced four deals:
  - **Investment in Civil Maps**, for its high-resolution 3D mapping capabilities
  - **Investment (along with China’s Baidu)** of $150 million in Velodyne for LiDAR systems;
  - **Purchase (outright)** of SAIPS, the Israeli company specializing in image and video processing algorithms;
  - **License (exclusive)** with Nirenberg Neuroscience LLC, focusing on machine vision algorithms
Functional Blocks Critical for ADS

- Mapping
- High-Level (Strategic) Controller
- Mid-Level (Tactical) Controller
- Low-Level (Actuation) Controller
- Driver & HMI
- Arbitration
- Detection & Perception (Sensing, etc.)
- Host Vehicle States
- Driving Environment
- Driving Environment
- Host Vehicle States
- Arbitration
- Driver & HMI
- Mid-Level (Tactical) Controller
- Low-Level (Actuation) Controller
- High-Level (Strategic) Controller
- Detection & Perception (Sensing, etc.)
- Mapping
Detection and Perception

Can Machine Learning (AI) Help (Self-Driving) Cars?
A.I. (Artificial Intelligence) & Machine Learning (Deep Learning)

• Becoming a Buzzword
  • Alpha Go beats (Human) Chess Champion (03/2016)

• Already broadly adopted at many high-tech companies
  • Google, Facebook, Microsoft, etc.

• A flurry of investments in start-ups
  • Red Hot in Silicon Valley

• White House Charts AI Future
  • Preparing for the Future of AI, 10/12/2016
Large-scale Semantic Description

Object Detection

Source: Trevor Darrell presentation
Large-scale Semantic Description

“A blue GMC van parked, in a back view”

“A man with glasses and a coat, facing back, walking away”

“An elderly man with a hat and glasses, facing the camera and talking”

“An entlebucher mountain dog sitting in a bag”

Object Detection
Semantic Segmentation
Pose Estimation
Attribute Classification
Fine-Grained Recognition
Action Recognition

“a man wearing long sleeves, possibly holding a shovel.”
“person last seen at 0900 in view 5”
“unusual farm worker”
A Case in Point, Hypothetically,

- Recent Tesla Incident (May 2016, Florida)

  - Supposedly, the Tesla (camera + radar) sensor did not recognize the “side of truck” versus the background sky;
  
  - (New Auto-Pilot software version from Tesla addressed the problem by improving radar signal processing)

- Can a “deep learning” system recognize an object that is “not the same” as a typical target?
AI (Deep Learning) for Cars

Something out of Left Field?

• Nvidia End to End Learning on Drive-PX2 for Self-Driving Cars (04/2016)
  – Trained a convolutional neural network (CNN) to map raw pixels from a single front-facing camera directly to steering commands

• Comma.ai will ship a $999 autonomous driving add-on by the end of this year (09/2016)
  – Tesla-like Auto-Pilot
Self-Driving Cars

Where are they going?
# State of the AV Industry

<table>
<thead>
<tr>
<th>Organization</th>
<th>Confirmed and Predicted Product Introduction</th>
<th>Predictions of Readiness for Fully Autonomous Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audi/VW</td>
<td>2016 – Piloted Driving</td>
<td>Available by 2021</td>
</tr>
<tr>
<td>BMW</td>
<td>2014 – traffic jam assist</td>
<td>Available by 2020</td>
</tr>
</tbody>
</table>
| Bosch              | 2017 – Integrated Highway Assist  
2020 - Highway Pilot | Auto Pilot by 2025                                                            |
| Continental        |                                                                 | Available by 2020                                      |
| Daimler-Benz       | 2014 – Intelligent Drive                                                       | Available by 2020                                      |
| Ford               | 2015 – fully assisted parking                                                  | Fleets of AV in 2021                                  |
| GM                 | 2017 – Super cruise                                                             |                                                       |
| Google             | 2015 – Driverless Pod prototype                                                | Available by 2018                                      |
| Honda              |                                                                 | Available by 2020                                      |
| Hyundai            |                                                                 | Available by 2030                                      |
| Mobile Eye         | 2016 – technology ready for OEMs                                               |                                                       |
| Nissan             | 2016 – traffic jam pilot  
2018 – multiple lane control                                                | Available by 2020                                      |
| Tesla              | 2015 – Lane Assist + ACC  
2016 – highly autonomous                                                      | Self-driving 2020-2025                                |
| Toyota             | Mid 2010s – highly autonomous                                                 |                                                       |
| Volvo              | 2015 – traffic jam assist  
2017 – Drive Me FOT in Sweden                                                   | Zero fatality cars by 2020                            |
Autonomous Vehicles Getting Real in 2016?

- Google Inks Driverless Car Pact With Fiat Chrysler (04/2016)
- Mobileye signed with automakers for AV in 2019 (05/2016)
- BMW to provide autonomous driving in 2021 (06/2016)
- Baidu to mass produce driverless cars in 5 years (07/2016)
- Uber testing self-driving cars for rides in Pittsburgh (08/2016)
- Ford to mass produce fully autonomous vehicles by 2021 (08/2016)
- VW aims at having fully autonomous vehicles by 2021 (08/2016)
- First “Drive Me” Volvo Car off production line and ready for launch for public FOT in early 2017 (09/2016)
Why Automation? Not just for Safety

This is boring and exhausting.

I am just so tired.

I have a lot of work to do.

I know I shouldn’t drive.

I like to chat with my friend.

Can you take the kid to school?
Why Automation? Not just for Safety

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Driver Assistance

Mobility Service
Not So Fast, You (Driverless) Cowboy!

• A.I. guardian-angel vehicles will dominate auto industry, says Gil Pratt, CEO Toyota Research Institute

• The vast majority of mainstream vehicles adopting autonomous driving features will be controlled by advanced driver assistance systems (ADAS) or "guardian angels" that learn over time

• Your car will eventually learn your driving habits and correct you
Why Buy a Cow when Milk is so Cheap?

- Smart Mobility LLC established as a subsidiary of Ford Motor Company (company news, 03/2016)
  - Move comes as Ford expands its business model to be both an auto and a mobility company
  - Ford targets fully autonomous vehicles for ride-sharing in 2021 (company news, 08/2016)

- Ford design chief prepares for a driverless society (The Verge, 10/17/2016)
  - In the next five years, Ford says it will transform from a company that sells ...Mustangs to ... autonomous vehicles and ... car-sharing ventures.
A Look Toward the Future
An All-too-Familiar Story

Research in Motion (Blackberry)

Apple

Nokia

Samsung
Landscape Shift in Auto and Tech Sectors

- A sitting duck
- A nimble mover
- An aggressor
- A newcomer
Will Innovation Win?

How Tesla Out-Innovates Traditional Carmakers

R&D intensity of Tesla and selected car manufacturers in 2015*

- Tesla: 17.7%
- VW: 6.4%
- BMW: 6.0%
- General Motors: 4.9%
- Ford: 4.5%
- Daimler: 4.4%
- Toyota: 3.7%
The Times They Are a-Changin’

“As the present now
Will later be past
The order is rapidly fading
And the first one now will later be last
Cause the times they are a-changing”

- Bob Dylan, Nobel Laureate
When Mobility Meets Automation

Automated Mobility Services
Disruptive Innovation in Transportation
Automated Mobility Service as a Case Study

• Automation will enhance ride sharing
  • Reduction or elimination of labor costs
  • Increased use of car sharing

• Fallout, Things at Stake
  • Much lower numbers (?) of cars on the road
  • $?00B carmaker market at risks
  • $190B car insurance, $90B finance, $100B parking, $300B aftermarket
  • ~4M people employed in auto industry
  • ~6M professional drivers

• Benefits
  • $1T disposable income
  • ?0,000 fatalities and ? millions of injuries
  • ? hours of time saved on roads
  • ? % reduction in green house gases

“Tesla Motors Inc. said it plans to charge buyers of its newest cars $8,000 to activate autonomous-driving technology, hinting those who do would be able to offset the cost through a ride-hailing network similar to Uber Technologies Inc. and Lyft Inc.”

(Washington Post, 10/21/2016)
Total

A Paradigm Shift

What will happen to transportation?

- Demand
- Traffic
- Car ownership
- Business model
- Parking
- Urban Planning
“The Future is here.
It is just not very evenly distributed.”

-William Ford Gibson, Novelist